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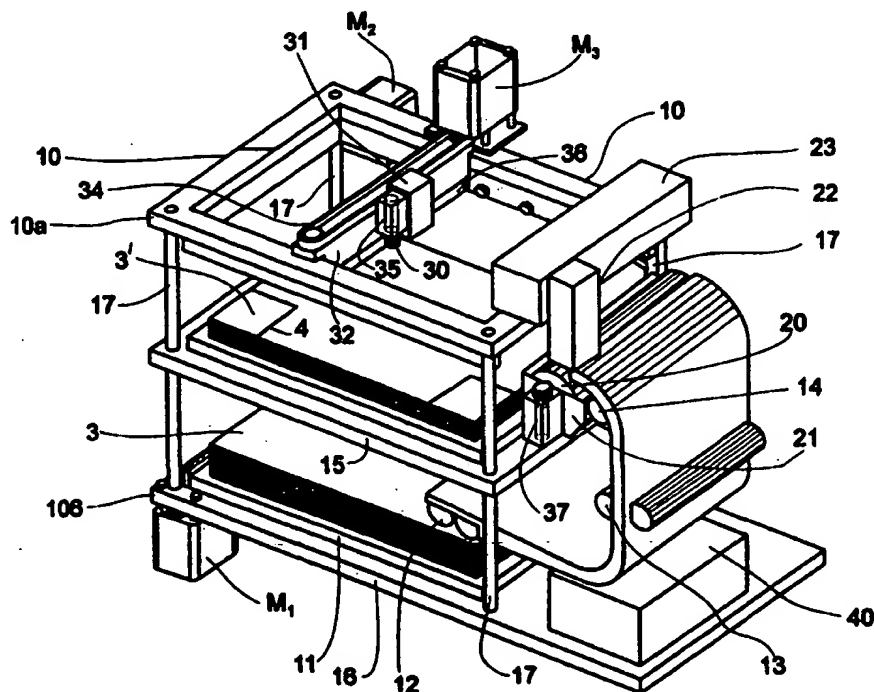
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(54) Title: METHOD AND APPARATUS FOR MAKING THREE-DIMENSIONAL OBJECTS

(57) Abstract

A method of and apparatus for making a three-dimensional object (2) made of a plurality of performed sheets (3), one atop the other. The method includes coating one side of one sheet (3) with adhesive using applicator (20), coating the adhesive with a release agent using applicator (22), bonding the opposite side of twice coating sheet (3) to a sheet (3) thereunder using adhesive on the surface of sheet (3) thereunder, and cutting twice coated sheet (3) using cutter (30). These steps are repeated until the desired number of sheets (3) is provided in a stack. The release agent is coated only in those areas of sheets (3) which will not be part of object (2), and cutting of each sheet (3) is along a contour corresponding to the contour of the same respective layer in object (2). After the steps have stopped, portion of the stack where the release layer is present and which is not part of object (2) is removed from the stack to give object (2).



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METHOD AND APPARATUS FOR MAKING THREE-DIMENSIONAL OBJECTSFIELD AND BACKGROUND OF THE INVENTION

The present invention relates to a method, and also to apparatus, for making three-dimensional objects, such as models, dies, molds, and the like.

The invention is particularly applicable to the method of making three-dimensional objects by bonding together a large number of relatively thin layers each having the contour of a thin slice of the object. Such methods are of particular interest today since they may take advantage of the highly-developed computer-aided design (CAD) techniques, as well as computer-aided manufacture (CAM) techniques. For example, US Patent 5,071,503 describes such

a technique in which each layer is a preformed sheet and is bonded to the partially-built object by applying an adhesive at locations defining, and within the confines of, the contour of the respective sheet, such that the portions of the sheet outside the contour are easily separated.

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OBJECT AND BRIEF SUMMARY OF THE INVENTION

An object of the present invention is to provide a novel method, and also apparatus, having advantages over the known techniques such as described in the above-cited patent.

According to one aspect of the present invention, there is provided a method of making a three-dimensional object constituted of a large number of thin preformed sheets each bonded on its opposite sides to the next adjacent sheets on its opposite sides, with each sheet cut along a contour corresponding to the contour of the respective layer constituted by the sheet in the object, characterized in: coating one side of each sheet, before being cut along its respective contour and bonded to the next adjacent sheet on that side, with a releasing agent which does not cover the surface of the sheet within the contour of the layer constituted by the respective sheet within the object, such that, after the respective sheet has been cut and bonded to the next adjacent sheet on that side, only the surface of the sheet within its respective contour is bonded to the next adjacent sheet, permitting the remaining non-bonded portion of the respective sheet not within the contour to be separated from the next adjacent sheet and the three-dimensional object.

Thus, whereas the method of the above-cited patent applies an adhesive to selected surfaces within the contour

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of the respective layer in the object, the present invention applies a releasing agent to selected surfaces outside of the contour.

The sheets may be precoated with an adhesive on one surface, or individually coated on the one surface during the application of the releasing agent to the opposite surface. The method of the present invention is thus easier to implement since it does not require precise control of the adhesive, but rather only precise control of the releasing agent, which is much easier to implement because of the nature of the two substances. Also, since the portions of the preformed sheets not to become a part of the produced object (i.e., the waste) are non-adhering to each other, they are easily removed from the produced object.

According to further features in the described preferred embodiments, the sheets are individually fed to, and stacked on, a horizontal table which is successively lowered as the sheets are successively stacked thereon. Each sheet is coated on its upper surface outside of its respective contour with the releasing agent, and on its under surface with the adhesive, as the sheet is fed to the horizontal table to be stacked on top of the other sheets thereon.

In one described preferred embodiment, each individual sheet is coated on its upper surface with the releasing agent by a releasing-agent applicator controlled to apply the releasing agent outside of the contour of the

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respective sheet while the sheet is moving. In a second described embodiment, each individual sheet is coated on its upper surface with the releasing agent by a moving releasing-agent applicator controlled to apply the releasing agent outside of the contour of the respective sheet while the sheet is stationary.

The invention also provides apparatus for making three-dimensional objects in accordance with the above-described technique.

Further features and advantages of the invention will be apparent from the description below.

BRIEF DESCRIPTION OF THE DRAWINGS

The invention is herein described, by way of example only, with reference to the accompanying drawings, wherein:

Fig. 1 is a three-dimensional view illustrating one form of apparatus constructed in accordance with the present invention;

Fig. 2 is a three-dimensional view from the opposite side of the apparatus of Fig. 1;

Figs. 3a-3c schematically illustrate how a three-dimensional object is produced by the method and apparatus illustrated in Figs. 1 and 2; and

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Figs. 4 and 5 are three-dimensional views corresponding to Figs. 1 and 2, respectively, illustrating a second form of apparatus constructed in accordance with the present invention.

DESCRIPTION OF PREFERRED EMBODIMENTS

The apparatus illustrated in Figs. 1 and 2 is used for making a three-dimensional object 2, such as illustrated in Fig. 3, from a large number of thin preformed sheets 3 bonded together with each sheet cut along a contour 4 corresponding to the contour of the respective layer in the object. The sheets 3, after being cut along their contours 4 and bonded together, are shown at 3' in Figs. 1 and 2. The waste remaining after the three-dimensional object 2 has been removed, is shown at 5 in Fig. 3.

The apparatus of Figs. 1 and 2 includes a machine frame 10 including an upper section 10a and a lower section 10b. The preformed sheets 3 used in making the three-dimensional object 2 are supported in the form of a vertical stack on a horizontal base 11 fixed to the lower section 10b of the machine frame. Each sheet 3 is fed from the top of the stack on base 11 by feed rolls 12, 13, 14, to the upper section 10a of the machine frame 10 to overlie a table 15 on which the three-dimensional object 2 is built layer-by-layer. Table 15 is driven in the vertical direction

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by an electrical motor M_1 and a closed-loop belt 16 coupled to rotate four screws 17 journaled between the upper and lower machine frame sections 10a, 10b, and threadedly received through the four corners of the table 15.

The upper section 10a of the machine frame 10 includes an adhesive applicator 20 which applies a coating of adhesive from a reservoir 21 to the under side of each sheet 3 as it is fed to the upper end 10a of the machine frame 10.

A second applicator 22 is also located at the upper end of the machine frame 10 to apply a releasing agent to the upper side of each sheet 3 as it is fed to the upper end 10a of the machine frame overlying table 15. Applicator 22 coats the upper surface of each sheet 3 with a releasing agent to cover the complete upper surface of the sheet except for the portion thereof within the contour 4 of the respective layer of the finished three-dimensional object 2 constituted by the respective sheet.

In the example illustrated in Figs. 1 and 2, the releasing agent applicator 22 is a print head which is movable along one orthogonal axis (the transverse Y-axis) as the sheet 3 is fed along the other orthogonal axis (the longitudinal X-axis) so that the applicator scans the complete upper surface of the sheet. The releasing-agent applicator 22 may be any suitable type of printing head, such as a liquid jet-ink printer, an impact-type printer, a laser printer, or the like. It applies to selected portions

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of the upper surface of each preformed sheet 3 a material, liquid or solid, which serves as a releasing agent with respect to the adhesive applied to the complete under surface of the sheet by applicator 20, such that an overlying sheet will not bond to an underlying sheet along the contacted surfaces which include the releasing agent, but will permit bonding where no releasing agent is present.

Applicator 22 is controlled by elements within its housing 23 to apply the releasing agent in the form of a negative pattern with respect to the contour 4 of the respective layer in the finished three-dimensional object 2. That is, the releasing agent is applied to cover all the surfaces of the preformed sheet 3 except the surfaces within the contour 4 of the respective layer in the finished object. Thus, each overlying sheet 3 will become bonded to the next adjacent underlying sheet 3 only within the contour 4 of the layer defined by the overlying sheet, and will not be bonded to the underlying sheet outside of that contour.

The apparatus illustrated in Figs. 1 and 2 further includes a cutting tool 30 which is controlled to cut along the contour 4 of the respective layer 3 in the finished object 2. Cutting tool 30 is mounted on a head 31 carried by a carriage 32. The carriage 32 is driven in the longitudinal direction (X-axis) with respect to the machine frame 10 by a motor M_2 and a closed-loop belt 33 (Fig. 2); whereas the head 31 is driven transversely of carriage 32 by another

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motor M_3 and a closed-loop belt 34. Cutter head 30 is also movable in the vertical direction by a solenoid 35 carried by the head 31 to an extended cutting position for cutting the underlying sheet 3 or to a retracted non-cutting position. A pressure roller 36 firmly presses the sheet, as it is being cut, against the previously processed sheets supported by table 15.

The adhesive applicator 20 is also provided with a solenoid 37 to move the adhesive applicator either to an operative position or to a non-operative position. For example, the adhesive applicator would be moved to a non-operative position when the first sheet 3 is fed so as to prevent that sheet from adhering to the table 11.

The illustrated apparatus further includes a controller, generally designated 40, for controlling the motors M_1 , M_2 , M_3 , the adhesive applicator 20, the releasing-agent applicator 22, the cutter tool 30, and the two solenoids 35 and 37, to produce the following operation:

A plurality of preformed rectangular sheets 3 to be used in producing the three-dimensional object 2, e.g., as illustrated in Fig. 3a, are supported in a vertical stack on the machine base plate 11 at the lower end 10b of the machine frame, and each is individually fed to the upper end 10a of the machine frame to overlie the table 15 on which the finished three-dimensional object 2 is built layer-by-layer. In the initial condition of the apparatus,

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table 15 is at its uppermost position, and as each layer of the object is formed on it, the table is successively moved vertically downwardly by motor M_1 belt 16 and screws 17, to accommodate the newly-added layer as it is applied to the object.

As each sheet 3, except the first sheet to contact table 11, is fed by the feed rollers 12, 13, 14 to the upper end 10a of the machine frame 10, the underside of the sheet is completely coated with adhesive by adhesive applicator 20, and its upper side is selectively coated with a releasing agent by applicator 22 which does not bond to the adhesive. The adhesive layer applied by applicator 20 covers the complete under surface of the respective sheet, whereas the releasing agent applied by applicator 22 covers only the upper surface of the sheet which does not come within the contour 4 of the respective layer of the sheet in the finished three-dimensional article. For example, if the respective layer to be formed by the sheet in the finished three-dimensional article is of a square contour, the rectangular sheet 3 to define that layer would be coated with the releasing agent only on its surface which is outwardly of the square defining the respective layer in the finished article; i.e., the surface within the square would not be covered by the releasing agent.

It will be appreciated that the contours of the finished-article layers to be produced by the preformed sheets 3 would be stored in a CAD or CAM format within

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controller 40, or in a separate memory accessible by the controller, to be used by the controller for controlling the releasing-agent applicator 22, and the cutter tool 30, when the respective sheet 3 is being processed.

After the respective sheet 3 has been placed on top of the stack on table 15, completely coated on its under surface with adhesive, and selectively coated on its upper surface with the releasing agent corresponding to the contour for that sheet, as described above, the cutter tool 30 is controlled, also by controller 40, to cut the sheet along the contour line 4 for the respective sheet. For this purpose, the controller 40 controls the two motors M_2 and M_3 driving the cutter tool 30 along the two orthogonal axes, and also controls the solenoid 35 for moving the cutter tool 30 to and away from its operative cutting position.

The three-dimensional model 2 is thus built up from the table 15, layer-by-layer, with each layer constituting a slice of the overall model. When all the layers have thus been applied, each layer adheres to the adjacent ones on both sides only along the portions thereof not coated with the releasing agent. Thus, after all the sheets for the entire three-dimensional object 2 have been cut and bonded together, the sheets adhere together only at their contacting surfaces within the contour 4 constituting the corresponding cross-section of the finished three-dimensional object, permitting the remaining non-bonded portions of the sheets not within such contour to

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be separated from the three-dimensional object. This is shown in Figs. 3a-3c, wherein it will be seen that the initial stack of sheets are shown at 3, the three-dimensional object produced therefrom is shown at 2, and the portions of the sheets not within the bonded contour surfaces, and to be separated from the object, are shown at 5.

Fig. 4 illustrates an apparatus very similar to that of Figs. 1 and 2. In order to facilitate understanding, those parts in the apparatus of Fig. 4 common to those of Figs. 1 and 2 are identified by the same reference numerals.

The main difference in the apparatus illustrated in Fig. 4 is that the releasing-agent applicator, designated 22' in Fig. 4, is carried on the same head 31' as the cutting tool 30. Therefore, in the apparatus of Fig. 4, the sheet 3 is stationary, not only at the time of cutting the contour by the cutting tool 30, but also at the time the releasing agent is applied by the applicator 22'. Thus, the releasing-agent applicator 22' is also driven both longitudinally and transversely with respect to the sheet 3 in order to selectively apply the releasing agent to the upper surface of the respective sheet as described above with respect to Figs. 1 and 2.

In substantially all other respects, the apparatus illustrated in Fig. 4 is constructed and operates as described above with respect to the apparatus of Figs. 1 and 2.

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The sheets 3 may be of any suitable plastic material, such as polyvinylchloride, epoxy resin, nylon etc. They should be of the appropriate thickness corresponding to the exactness required in the finished object to be produced by the apparatus. Preferably, the sheets 3 should be of the order of 0.1 mm in thickness, thereby requiring about 100 such sheets to be processed for each one-centimeter height of the three-dimensional object to be produced.

The releasing agent may be of any suitable material which does not bond to the adhesive used. As one example, the releasing agent may be a wax composition.

While the illustrated apparatus shows the adhesive being applied to the under surface of each sheet at the time each sheet is processed, it will be appreciated that the preformed sheets may be pre-coated with the adhesive before being applied to the apparatus. It is also contemplated that the preformed sheets may be bonded together by applying a solvent to the under surface of the respective sheet to thereby soften it and to promote its bonding to the overlying sheet except where the upper surface of the respective sheet is selectively covered by the releasing agent. It is further contemplated that an adhesive need not be used, but rather that the sheets themselves be bonded by heat and/or pressure except at those surfaces selectively covered by the releasing agent, which heat and/or pressure would be applied to the entire stack of sheets. The cutting tool 30 may be heated. The bonding may be performed before,

during, or after the cutting tool has been applied to cut the contour. The releasing agent could be coloured according to the desired colour of the produced object, and could be applied in any known manner, e.g., electrostatically, by a laser, by a thermal printer, etc. The adhesive applicator could also be mounted for movement along one axis (e.g., transversely) as the preformed sheet is moved along the other axis.

Also, the releasing agent can be applied directly on top of the glue, or below the glue on the same side of the sheet, in which case the releasing agent applicator 22 would be mounted on the same side as the adhesive applicator 20. Further, the sheet could be completely pre-coated with the releasing agent, and such agent removed from the portion of the sheet to be glued, in which case unit 22 in Fig. 1 would be a "removing" unit, to remove the unwanted portion of the releasing agent mechanically, chemically, by laser, etc. Further, the glue could be applied to the upper face of the sheet, and the releasing agent on the bottom face, rather than vice versa described above.

Alternatively, rather than utilizing an adhesive from adhesive applicator 20 that will bond to an adjacent sheet except in areas to which the releasing agent from applicator 22 is applied, applicator 20 can apply an adhesive having the characteristics such that it will bond to an adjacent sheet only in areas to which an activating agent is applied by applicator 22. In this configuration, the activating agent is applied only to the portion within the contour 4, such that adjacent sheets will bond only in the contour area to which the activating agent is applied.

Many other variations, modifications and applications of the invention will be apparent.

WHAT IS CLAIMED IS :

1. A method of making a three-dimensional object constituted of a large number of thin preformed sheets each bonded on its opposite sides to the next adjacent sheets on its opposite sides, with each sheet cut along a contour corresponding to the contour of the respective layer constituted by the sheet in the object, characterized in: coating one side of each sheet, before being cut along its respective contour and bonded to the next adjacent sheet on that side, with a releasing agent which does not cover the surface of the sheet within the contour of the layer constituted by the respective sheet within said object, such that, after the respective sheet has been cut and bonded to the next adjacent sheet on that side, only the surface of the sheet within its respective contour is bonded to said next adjacent sheet, permitting the remaining non-bonded portion of the respective sheet not within said contour to be separated from the next adjacent sheet and the three-dimensional object.

2. The method according to Claim 1, wherein the side of each sheet opposite to that coated with said releasing agent is covered on its complete surface with an adhesive to promote the bonding of all said sheets to each other except where covered by said releasing agent.

3. The method according to Claim 2, wherein said adhesive is applied to the under surfaces of said sheets,

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and said releasing agent is applied to the upper surfaces of said sheets.

4. The method according to either of Claims 2 or 3, wherein said sheets are individually fed to and stacked on a horizontal table which is successively lowered as the sheets are successively stacked thereon.

5. The method according to Claim 4, wherein each individual sheet is coated on its upper surface outside of its respective contour with said releasing agent as the sheet is fed to said horizontal table to be stacked on top of the other sheets thereon.

6. The method according to Claim 5, wherein each individual sheet is coated on its upper surface with said releasing agent by a releasing-agent applicator controlled to apply the releasing agent outside of the contour of the respective sheet while the sheet is moving.

7. The method according to Claim 5, wherein each individual sheet is coated on its upper surface with said releasing agent by a moving releasing-agent applicator controlled to apply the releasing agent outside of the contour of the respective sheet while the sheet is stationary.

8. The method according to either of Claims 6 or 7, wherein each individual sheet is cut along its respective contour by a cutting tool which is driven in two dimensions to trace the respective contour while the sheet is

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stationary, and in a third dimension to either a cutting or non-cutting position.

9. The method according to any one of Claims 5-8, wherein each individual sheet is coated on its complete lower surface with said adhesive as the sheet is fed to said horizontal table to be stacked on top of the other sheets thereon.

10. The method according to any one of Claims 5-8, wherein each sheet is precoated on its under surface with said adhesive.

11. Apparatus for making a three-dimensional object constituted of a large number of thin preformed sheets each bonded on its opposite sides to the next adjacent sheets on its opposite sides, with each sheet cut by a cutting tool along a contour corresponding to the contour of the respective layer constituted by the sheet in the object, characterized in that said apparatus includes a releasing-agent applicator for applying a coating on one side of each sheet, before being cut along its respective contour and bonded to the next adjacent sheet on that side, with a releasing agent which does not cover the surface of the sheet within the contour of the layer constituted by the respective sheet within said object, such that, after the respective sheet has been cut and bonded to the next adjacent sheet on that side, only the surface of the sheet within its respective contour is bonded to said next adjacent sheet, permitting the remaining non-bonded portion

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of the respective sheet not within said contour to be separated from the next adjacent sheet and the three-dimensional object.

12. The apparatus according to Claim 11, wherein said releasing-agent applicator is located to apply said releasing agent to the upper surfaces of said sheets.

13. The apparatus according to Claim 12, wherein said apparatus further includes: a horizontal table; a feeder for feeding said sheets individually to, and stacking them on, said horizontal table; and a drive for lowering said table as said sheets are successively stacked thereon.

14. The apparatus according to Claim 13, wherein said drive comprises a rotary motor and screws driven by said motor and coupled to the corners of said horizontal table for raising and lowering the table.

15. The apparatus according to either of Claims 13 or 14, wherein said releasing-agent applicator is located to apply said releasing agent to the upper surface of each sheet as it is fed to said horizontal table to be stacked on top of the other sheets on the table.

16. The apparatus according to Claim 15, wherein said releasing-agent applicator is controlled to apply said releasing agent outside of the contour of the respective sheet while the sheet is moving.

17. The apparatus according to Claim 15, wherein said releasing-agent applicator is movable and is driven to

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apply the releasing agent outside of the contours of the respective sheet while the sheet is stationary.

18. The apparatus according to any one of Claims 15-17, wherein said cutting tool is driven in two dimensions to trace the respective contour of the sheet while the sheet is stationary, and in a third dimension to either a cutting or a non-cutting position.

19. The apparatus according to any one of Claims 15-17, wherein said releasing-agent applicator and said cutting tool are carried by a common head which is driven in two dimensions to define the contour of the respective sheet.

20. The apparatus according to any one of Claims 15-19, wherein said apparatus further includes an adhesive applicator for applying an adhesive coating to the under surface of each sheet as it is fed to said horizontal table, to effect the bonding thereof to the underlying sheet at the portions of the underlying sheet not covered by the releasing agent.

21. A method of making a three-dimensional object constituted of a large number of thin preformed sheets each bonded on its opposite sides to the next adjacent sheets on its opposite sides, with each sheet cut along a contour corresponding to respective layer constituted by the sheet in the object. characterized in: coating one side of each sheet, before being cut along its respective contour and bonded to the next adjacent sheet on that side with an activating agent that only covers the surface of the sheet within the contour of layer constituted by the respective sheet within said object. such that only the surface of the sheet within its respective contour is bonded to its next adjacent sheet, permitting the remaining non-bonded portion of the respective sheet not within said contour to be separated from the next adjacent sheet and the three-dimensional object.

22. The method according to claim 21, wherein the side of each sheet opposite to that coated with said activating agent is covered on its complete surface with an adhesive that is only activated if placed into contact with an activating agent to promote the bonding of all said sheets to each other only in areas covered with said activating agent.

23. Apparatus for making a three-dimensional object constituted of a large number of thin preformed sheets each bonded on its opposite sides to the next adjacent sheets on its opposite sides, with each sheet cut by a cutting tool along a contour corresponding to contour of the respective layer constituted by the sheet in the

object. characterized in said apparatus includes an activating agent applicator for applying a coating on one side of each sheet, before being cut along its respective contour and bonded to the next adjacent sheet on that side with an activating agent which only covers the surface of the sheet within the contour of layer constituted by the respective sheet within said object, such that, after the respective sheet has been cut and bonded to the next adjacent sheet on that side, only the surface of the sheet within its respective contour is bonded to its next adjacent sheet. permitting the remaining non-bonded portion of the respective sheet not within said contour to be separated from the next adjacent sheet and the three-dimensional object.

24. The apparatus according to claim 23, wherein said activating agent applicator is located to apply said activating agent to the upper surfaces of said sheets.

25. The apparatus according to claim 24, wherein said apparatus further includes: a horizontal table; a feeder for feeding said sheets individually to, and stacking them on, said horizontal table; and a drive for lowering said table as said sheets are successively stacked thereon.

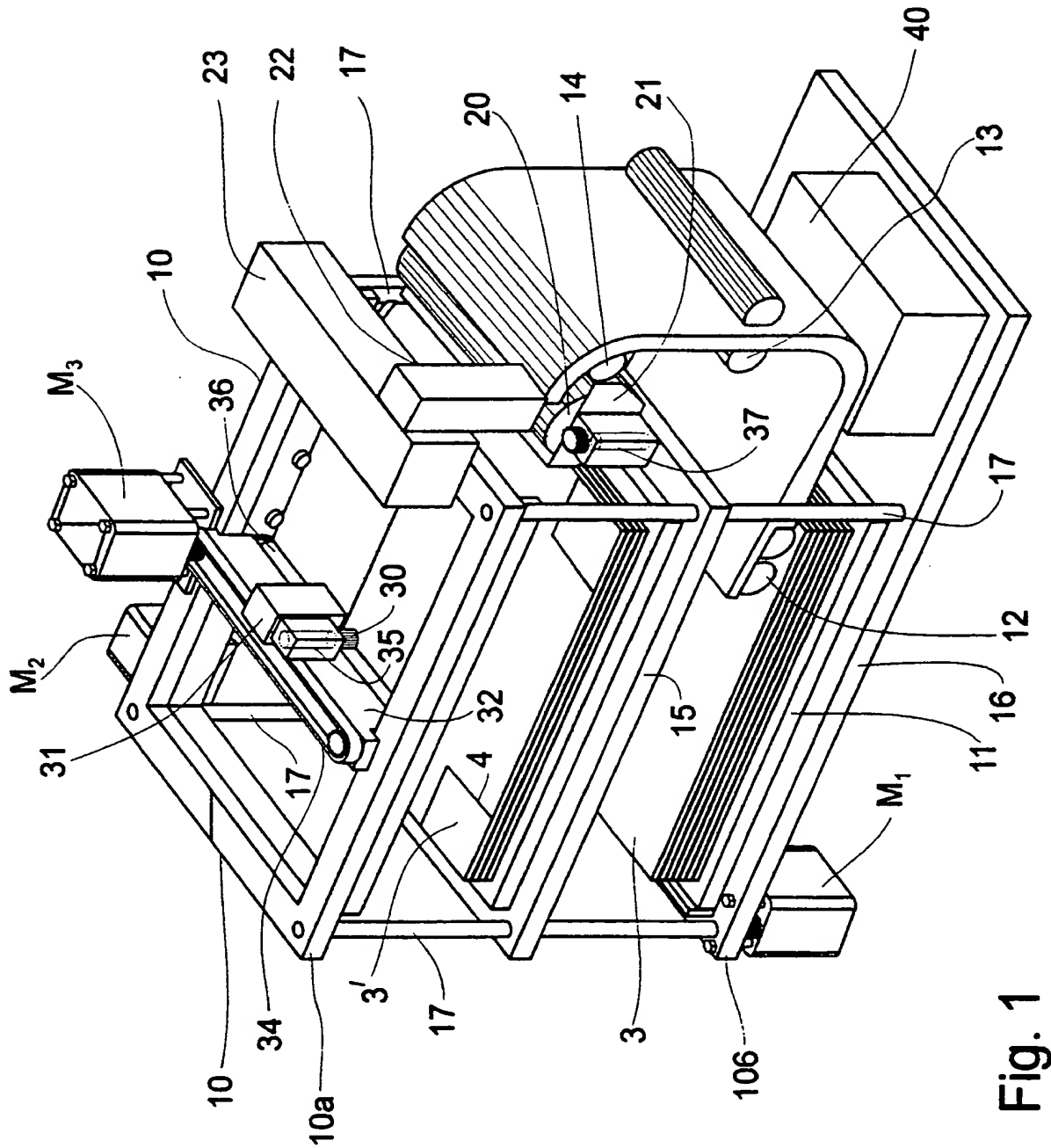


Fig. 1

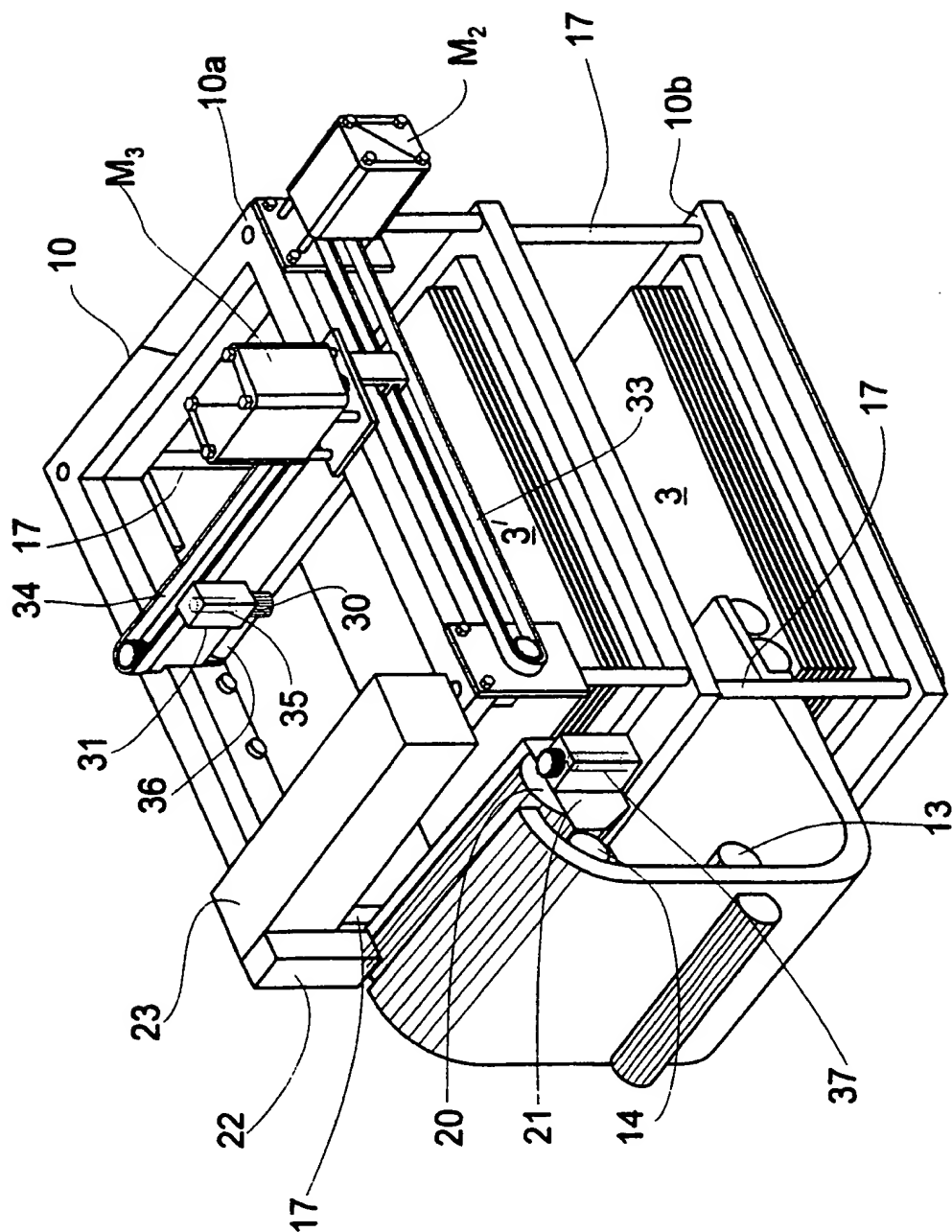
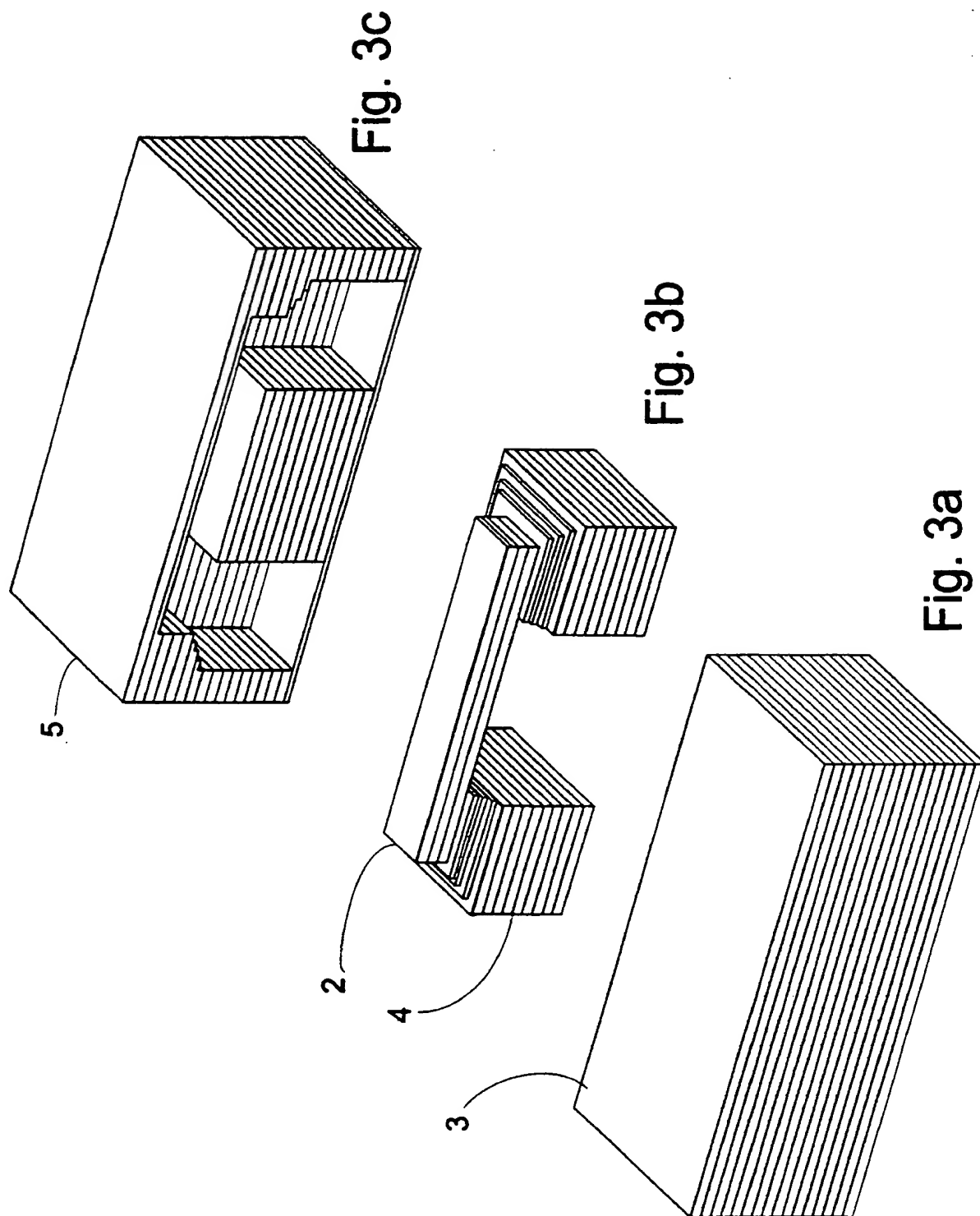


Fig. 2



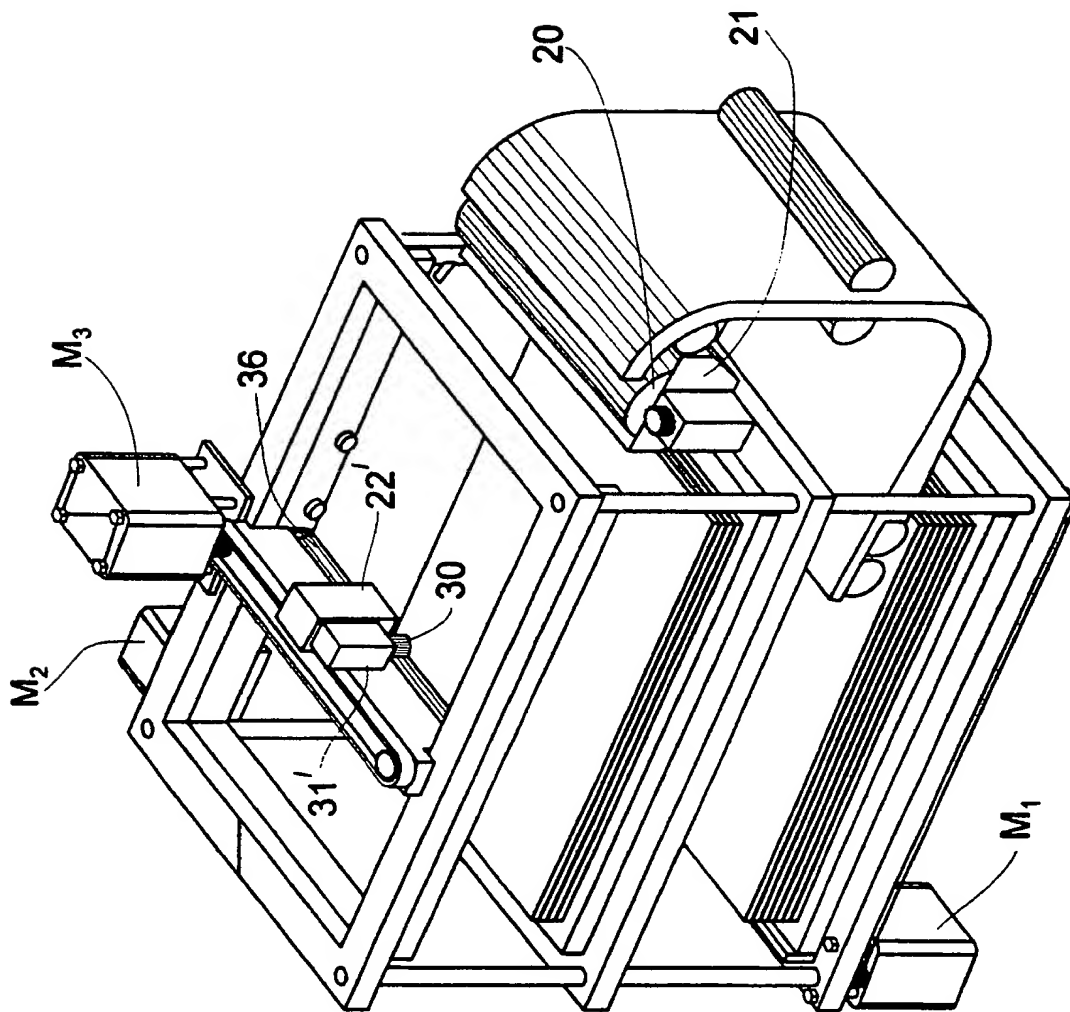


Fig. 4

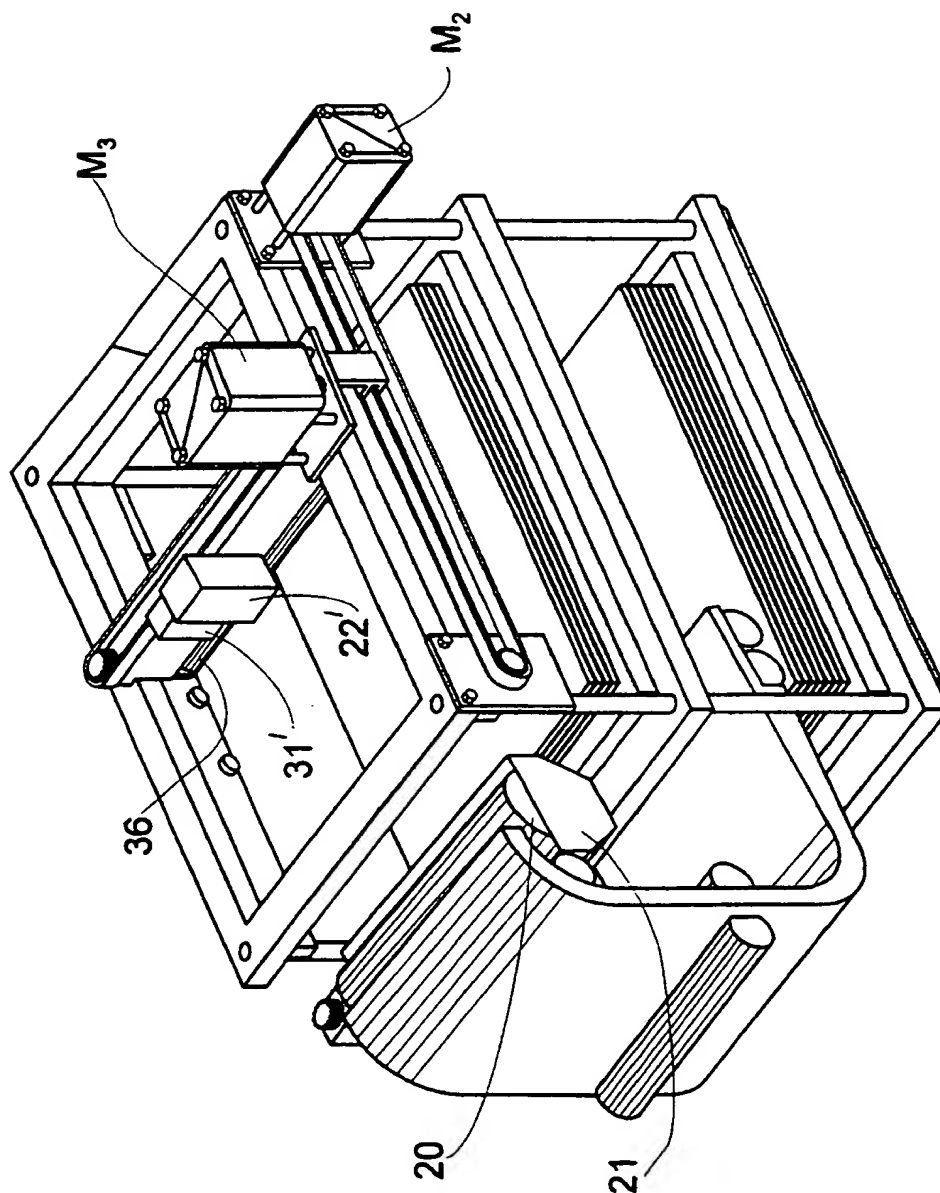


Fig. 5

INTERNATIONAL SEARCH REPORT

International application No.
PCT/IL98/00623

A. CLASSIFICATION OF SUBJECT MATTER

IPC(6) :B32B 31/00

US CL :Please See Extra Sheet.

According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)

U.S. : 156/64, 267, 268, 277, 289, 290, 353, 356, 387, 512, 516, 529, 558, 563; 427/207.1, 261, 402

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched
NONEElectronic data base consulted during the international search (name of data base and, where practicable, search terms used)
NONE

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
Y	US 5,015,312 A (KINZIE) 14 May 1991, col. 5, line 14, to col. 12, line 61.	1-17 and 21-25
Y	US 5,578,155 A (KAWAGUCHI) 26 November 1996, col. 5, to col. 9, line 5.	1-17 and 21-25
Y,P	US 5,730,817 A (FEYGIN et al) 24 March 1998, col. 3, line 36, to col. 12, line 65.	1-17 and 21-25

☐ Further documents are listed in the continuation of Box C. ☐ See patent family annex.

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E earlier document published on or after the international filing date	*Y* document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art
L document which may throw doubts on priority claim(s) or which is cited to establish the publication date of another citation or other special reason (as specified)	*Z* document member of the same patent family
O document referring to an oral disclosure, use, exhibition or other means	
P document published prior to the international filing date but later than the priority date claimed	

Date of the actual completion of the international search

19 APRIL 1999

Date of mailing of the international search report

14 MAY 1999

Name and mailing address of the ISA/US
Commissioner of Patents and Trademarks
Box PCT
Washington, D.C. 20231

Facsimile No. (703) 305-3230

Authorized officer

DAVID A. SUMMONS

Telephone No. (703) 308-1972

INTERNATIONAL SEARCH REPORT

International application No.
PCT/IL98/00623

Box I Observations where certain claims were found unsearchable (Continuation of item 1 of first sheet)

This international report has not been established in respect of certain claims under Article 17(2)(a) for the following reasons:

1. ☐ Claims Nos.:
because they relate to subject matter not required to be searched by this Authority, namely:

2. ☐ Claims Nos.:
because they relate to parts of the international application that do not comply with the prescribed requirements to such an extent that no meaningful international search can be carried out, specifically:

3. ☒ Claims Nos.: 18-20
because they are dependent claims and are not drafted in accordance with the second and third sentences of Rule 6.4(a).

Box II Observations where unity of invention is lacking (Continuation of item 2 of first sheet)

This International Searching Authority found multiple inventions in this international application, as follows:

1. ☐ As all required additional search fees were timely paid by the applicant, this international search report covers all searchable claims.
2. ☐ As all searchable claims could be searched without effort justifying an additional fee, this Authority did not invite payment of any additional fee.
3. ☐ As only some of the required additional search fees were timely paid by the applicant, this international search report covers only those claims for which fees were paid, specifically claims Nos.:

4. ☐ No required additional search fees were timely paid by the applicant. Consequently, this international search report is restricted to the invention first mentioned in the claims; it is covered by claims Nos.:

Remark on Protest

☐
☐

- The additional search fees were accompanied by the applicant's protest.
No protest accompanied the payment of additional search fees.

INTERNATIONAL SEARCH REPORT

International application No.
PCT/IL98/00623

A. CLASSIFICATION OF SUBJECT MATTER:
US CL :

156/64, 267, 268, 277, 289, 290, 353, 356, 387, 512, 516, 529, 558, 563; 427/207.1, 261, 402

WHAT IS CLAIMED IS :

1. A method of making a three-dimensional object constituted of a large number of thin preformed sheets each bonded on its opposite sides to the next adjacent sheets on its opposite sides, with each sheet cut along a contour corresponding to the contour of the respective layer constituted by the sheet in the object, characterized in: coating one side of each sheet, before being cut along its respective contour and bonded to the next adjacent sheet on that side, with a releasing agent which does not cover the surface of the sheet within the contour of the layer constituted by the respective sheet within said object, such that, after the respective sheet has been cut and bonded to the next adjacent sheet on that side, only the surface of the sheet within its respective contour is bonded to said next adjacent sheet, permitting the remaining non-bonded portion of the respective sheet not within said contour to be separated from the next adjacent sheet and the three-dimensional object.

2. The method according to Claim 1, wherein the side of each sheet opposite to that coated with said releasing agent is covered on its complete surface with an adhesive to promote the bonding of all said sheets to each other except where covered by said releasing agent.

3. The method according to Claim 2, wherein said adhesive is applied to the under surfaces of said sheets,

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and said releasing agent is applied to the upper surfaces of said sheets.

4. The method according to either of Claims 2 or 3, wherein said sheets are individually fed to and stacked on a horizontal table which is successively lowered as the sheets are successively stacked thereon.

5. The method according to Claim 4, wherein each individual sheet is coated on its upper surface outside of its respective contour with said releasing agent as the sheet is fed to said horizontal table to be stacked on top of the other sheets thereon.

6. The method according to Claim 5, wherein each individual sheet is coated on its upper surface with said releasing agent by a releasing-agent applicator controlled to apply the releasing agent outside of the contour of the respective sheet while the sheet is moving.

7. The method according to Claim 5, wherein each individual sheet is coated on its upper surface with said releasing agent by a moving releasing-agent applicator controlled to apply the releasing agent outside of the contour of the respective sheet while the sheet is stationary.

8. The method according to either of Claims 6 or 7, wherein each individual sheet is cut along its respective contour by a cutting tool which is driven in two dimensions to trace the respective contour while the sheet is

stationary, and in a third dimension to either a cutting or non-cutting position.

9. The method according to any one of Claims 5-8, wherein each individual sheet is coated on its complete lower surface with said adhesive as the sheet is fed to said horizontal table to be stacked on top of the other sheets thereon.

10. The method according to any one of Claims 5-8, wherein each sheet is precoated on its under surface with said adhesive.

11. Apparatus for making a three-dimensional object constituted of a large number of thin preformed sheets each bonded on its opposite sides to the next adjacent sheets on its opposite sides, with each sheet cut by a cutting tool along a contour corresponding to the contour of the respective layer constituted by the sheet in the object, characterized in that said apparatus includes a releasing-agent applicator for applying a coating on one side of each sheet, before being cut along its respective contour and bonded to the next adjacent sheet on that side, with a releasing agent which does not cover the surface of the sheet within the contour of the layer constituted by the respective sheet within said object, such that, after the respective sheet has been cut and bonded to the next adjacent sheet on that side, only the surface of the sheet within its respective contour is bonded to said next adjacent sheet, permitting the remaining non-bonded portion

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of the respective sheet not within said contour to be separated from the next adjacent sheet and the three-dimensional object.

12. The apparatus according to Claim 11, wherein said releasing-agent applicator is located to apply said releasing agent to the upper surfaces of said sheets.

13. The apparatus according to Claim 12, wherein said apparatus further includes: a horizontal table; a feeder for feeding said sheets individually to, and stacking them on, said horizontal table; and a drive for lowering said table as said sheets are successively stacked thereon.

14. The apparatus according to Claim 13, wherein said drive comprises a rotary motor and screws driven by said motor and coupled to the corners of said horizontal table for raising and lowering the table.

15. The apparatus according to either of Claims 13 or 14, wherein said releasing-agent applicator is located to apply said releasing agent to the upper surface of each sheet as it is fed to said horizontal table to be stacked on top of the other sheets on the table.

16. The apparatus according to Claim 15, wherein said releasing-agent applicator is controlled to apply said releasing agent outside of the contour of the respective sheet while the sheet is moving.

17. The apparatus according to Claim 15, wherein said releasing-agent applicator is movable and is driven to

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apply the releasing agent outside of the contours of the respective sheet while the sheet is stationary.

18. The apparatus according to any one of Claims 15-17, wherein said cutting tool is driven in two dimensions to trace the respective contour of the sheet while the sheet is stationary, and in a third dimension to either a cutting or a non-cutting position.

19. The apparatus according to any one of Claims 15-17, wherein said releasing-agent applicator and said cutting tool are carried by a common head which is driven in two dimensions to define the contour of the respective sheet.

20. The apparatus according to any one of Claims 15-19, wherein said apparatus further includes an adhesive applicator for applying an adhesive coating to the under surface of each sheet as it is fed to said horizontal table, to effect the bonding thereof to the underlying sheet at the portions of the underlying sheet not covered by the releasing agent.

21. A method of making a three-dimensional object constituted of a large number of thin preformed sheets each bonded on its opposite sides to the next adjacent sheets on its opposite sides, with each sheet cut along a contour corresponding to respective layer constituted by the sheet in the object, characterized in: coating one side of each sheet, before being cut along its respective contour and bonded to the next adjacent sheet on that side with an activating agent that only covers the surface of the sheet within the contour of layer constituted by the respective sheet within said object, such that only the surface of the sheet within its respective contour is bonded to its next adjacent sheet, permitting the remaining non-bonded portion of the respective sheet not within said contour to be separated from the next adjacent sheet and the three-dimensional object.

22. The method according to claim 21, wherein the side of each sheet opposite to that coated with said activating agent is covered on its complete surface with an adhesive that is only activated if placed into contact with an activating agent to promote the bonding of all said sheets to each other only in areas covered with said activating agent.

23. Apparatus for making a three-dimensional object constituted of a large number of thin preformed sheets each bonded on its opposite sides to the next adjacent sheets on its opposite sides, with each sheet cut by a cutting tool along a contour corresponding to contour of the respective layer constituted by the sheet in the

object, characterized in said apparatus includes an activating agent applicator for applying a coating on one side of each sheet, before being cut along its respective contour and bonded to the next adjacent sheet on that side with an activating agent which only covers the surface of the sheet within the contour of layer constituted by the respective sheet within said object, such that, after the respective sheet has been cut and bonded to the next adjacent sheet on that side, only the surface of the sheet within its respective contour is bonded to its next adjacent sheet, permitting the remaining non-bonded portion of the respective sheet not within said contour to be separated from the next adjacent sheet and the three-dimensional object.

24. The apparatus according to claim 23, wherein said activating agent applicator is located to apply said activating agent to the upper surfaces of said sheets.

25. The apparatus according to claim 24, wherein said apparatus further includes: a horizontal table; a feeder for feeding said sheets individually to, and stacking them on, said horizontal table; and a drive for lowering said table as said sheets are successively stacked thereon.

INTERNATIONAL SEARCH REPORT

International application No.
PCT/IL98/00623

A. CLASSIFICATION OF SUBJECT MATTER

IPC(6) : B32B 31/00

US CL : Please See Extra Sheet.

According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)

U.S. : 156/64, 267, 268, 277, 289, 290, 353, 356, 387, 512, 516, 529, 558, 563; 427/207.1, 261, 402

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched
NONEElectronic data base consulted during the international search (name of data base and, where practicable, search terms used)
NONE

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
Y	US 5,015,312 A (KINZIE) 14 May 1991, col. 5, line 14, to col. 12, line 61.	1-17 and 21-25
Y	US 5,578,155 A (KAWAGUCHI) 26 November 1996, col. 5, to col. 9, line 5.	1-17 and 21-25
Y,P	US 5,730,817 A (FEYGIN et al) 24 March 1998, col. 3, line 36, to col. 12, line 65.	1-17 and 21-25

☐ Further documents are listed in the continuation of Box C. ☐ See patent family annex.

* Special categories of cited documents:	*T* later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention
A document defining the general state of the art which is not considered to be of particular relevance	*X* document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone
E earlier document published on or after the international filing date	*Y* document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art
L document which may throw doubts on priority claim(s) or which is cited to establish the publication date of another citation or other special reason (as specified)	*G* document member of the same patent family
O document referring to an oral disclosure, use, exhibition or other means	
P document published prior to the international filing date but later than the priority date claimed	

Date of the actual completion of the international search

19 APRIL 1999

Date of mailing of the international search report

14 MAY 1999

Name and mailing address of the ISA/US
Commissioner of Patents and Trademarks
Box PCT
Washington, D.C. 20231

Facsimile No. (703) 305-3230

Authorized officer

DAVID A. SIMMONS

Telephone No. (703) 308-1972

INTERNATIONAL SEARCH REPORT

International application No.
PCT/IL98/00623

Box I Observations where certain claims were found unsearchable (Continuation of item 1 of first sheet)

This international report has not been established in respect of certain claims under Article 17(2)(a) for the following reasons:

1. ☐ Claims Nos.:
because they relate to subject matter not required to be searched by this Authority, namely:
2. ☐ Claims Nos.:
because they relate to parts of the international application that do not comply with the prescribed requirements to such an extent that no meaningful international search can be carried out, specifically:
3. ☒ Claims Nos.: 18-20
because they are dependent claims and are not drafted in accordance with the second and third sentences of Rule 6.4(a).

Box II Observations where unity of invention is lacking (Continuation of item 2 of first sheet)

This International Searching Authority found multiple inventions in this international application, as follows:

1. ☐ As all required additional search fees were timely paid by the applicant, this international search report covers all searchable claims.
2. ☐ As all searchable claims could be searched without effort justifying an additional fee, this Authority did not invite payment of any additional fee.
3. ☐ As only some of the required additional search fees were timely paid by the applicant, this international search report covers only those claims for which fees were paid, specifically claims Nos.:
4. ☐ No required additional search fees were timely paid by the applicant. Consequently, this international search report is restricted to the invention first mentioned in the claims; it is covered by claims Nos.:

Remark on Protest

- ☐ The additional search fees were accompanied by the applicant's protest.
☐ No protest accompanied the payment of additional search fees.

INTERNATIONAL SEARCH REPORT

International application No.
PCT/IL98/00623

A. CLASSIFICATION OF SUBJECT MATTER:
US CL :

156/64, 267, 268, 277, 289, 290, 353, 356, 387, 512, 516, 529, 558, 563; 427/207.1, 261, 402

PATE COOPERATION TREATY

PCT

NOTIFICATION OF THE RECORDING
OF A CHANGE(PCT Rule 92bis.1 and
Administrative Instructions, Section 422)

From the INTERNATIONAL BUREAU

To:

FRIEDMAN, Mark, M.
Beit Samueloff
Haomanim Street 7
67897 Tel Aviv
ISRAËL

Date of mailing (day/month/year) 06 March 2000 (06.03.00)	IMPORTANT NOTIFICATION
Applicant's or agent's file reference 1529/1	
International application No. PCT/IL98/00623	International filing date (day/month/year) 05 January 1999 (05.01.99)

1. The following indications appeared on record concerning:

☒ the applicant ☒ the inventor ☐ the agent ☐ the common representative

Name and Address BAR-EREZ, Yosi 26 Hagfanim 49935 Kfar Sirkin Israel	State of Nationality IL	State of Residence IL
	Telephone No.	
	Facsimile No.	
	Teleprinter No.	

2. The International Bureau hereby notifies the applicant that the following change has been recorded concerning:

☒ the person ☐ the name ☐ the address ☐ the nationality ☐ the residence

Name and Address 3.D.P. LTD. 26 Hagfanim Street 49935 Kfar Sirkin Israel	State of Nationality IL	State of Residence IL
	Telephone No.	
	Facsimile No.	
	Teleprinter No.	

3. Further observations, if necessary:

The applicant/inventor of record has assigned his rights to the person in box 2, who should now be registered as the applicant for all designated States except the United States of America.

4. A copy of this notification has been sent to:

<input checked="" type="checkbox"/> the receiving Office	<input checked="" type="checkbox"/> the designated Offices concerned
<input type="checkbox"/> the International Searching Authority	<input type="checkbox"/> the elected Offices concerned
<input type="checkbox"/> the International Preliminary Examining Authority	<input type="checkbox"/> other:

The International Bureau of WIPO 34, chemin des Colombettes 1211 Geneva 20, Switzerland Facsimile No.: (41-22) 740.14.35	Authorized officer Ingrid Aulich Telephone No.: (41-22) 338.83.38
---	---

PATENT COOPERATION TREATY

PCT

NOTIFICATION OF ELECTION

(PCT Rule 61.2)

From the INTERNATIONAL BUREAU

To:

Assistant Commissioner for Patents
United States Patent and Trademark
Office
Box PCT
Washington, D.C.20231
ÉTATS-UNIS D'AMÉRIQUE

in its capacity as elected Office

Date of mailing (day/month/year) 06 March 2000 (06.03.00)	Applicant's or agent's file reference 1529/1
International application No. PCT/IL98/00623	Priority date (day/month/year) 05 January 1998 (05.01.98)
International filing date (day/month/year) 05 January 1999 (05.01.99)	Applicant BAR-EREZ, Yosi

1. The designated Office is hereby notified of its election made:

☒ in the demand filed with the International Preliminary Examining Authority on:

19 July 1999 (19.07.99)

☐ in a notice effecting later election filed with the International Bureau on:2. The election ☒ was☐ was not

made before the expiration of 19 months from the priority date or, where Rule 32 applies, within the time limit under Rule 32.2(b).

The International Bureau of WIPO 34, chemin des Colombettes 1211 Geneva 20, Switzerland	Authorized officer Ingrid Aulich
Facsimile No.: (41-22) 740.14.35	Telephone No.: (41-22) 338.83.38

PATENT COOPERATION TREATY

From the INTERNATIONAL BUREAU

PCTCOMMUNICATION IN CASES FOR WHICH
NO OTHER FORM IS APPLICABLE

To:

FRIEDMAN, Mark, M.
Beit Samueloff
7 Haomanim Street
67897 Tel Aviv
ISRAËL

Date of mailing (day/month/year) 27 January 1999 (27.01.1999)	
Applicant's or agent's file reference 1529/1	REPLY DUE see paragraph 1 below
International application No. PCT/IL98/00623	International filing date (day/month/year) 05 January 1999 (05.01.1999)
Applicant 1529/1	BAR-EREZ, Yosi

1. ☐ REPLY DUE within _____ months/days from the above date of mailing
- ☐ NO REPLY DUE, however, see below
- ☒ IMPORTANT COMMUNICATION
- ☐ INFORMATION ONLY

2. COMMUNICATION:

Please be informed that the receiving Office has notified the International Bureau that the international filing date for the above-identified international application should read:

05 January 1999 (05.01.1999)

instead of:

25 December 1998 (25.12.1998).

A copy of this communication has been sent to the receiving Office (RO/IL), the International Searching Authority (ISA/US), and the designated Offices which have already been notified of the receipt of the record copy.

The International Bureau of WIPO 34, chemin des Colombettes 1211 Geneva 20, Switzerland	Authorized officer Maria Victoria CORTIELLO
Facsimile No. (41-22) 740.14.35	Telephone No. (41-22) 338.83.38